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PORTABLE TEST RANGE AND ITS APPLICATION TO SIDE-LOOKING SONAR.(U)
JAN 78 R W UHRICH, J M WALTON, S J WATSON
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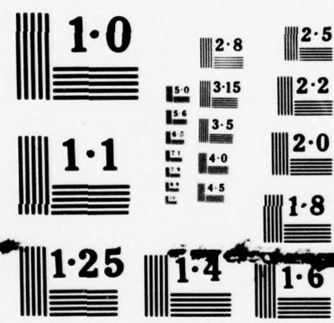

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PORTABLE TEST RANGE AND ITS APPLICATION TO SIDE-LOOKING SONAR

RW Uhrich
JM Walton
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15 January 1978

Final Report: May 1976 - October 1977

Prepared for
Naval Sea Systems Command

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To convert from	To	Multiply by
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feet	metres	3.048×10^{-1}
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This document describes a one-year effort to develop techniques by which underwater search sensors can be quantitatively evaluated in actual ocean environments. Side-Looking Sonar (SLS), being the primary means of underwater search, was the focus of this effort. However, many of the methods developed can be applied directly to evaluation of other types of search sensors.

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GLOSSARY

ADOSS	Advanced Deep Ocean Search System
APL	Applied Physics Laboratory
ARL	Applied Research Laboratory
ATNAV	Acoustic Transducer Navigation System
AUSS	Advanced Unmanned Search System
CEL	Civil Engineering Laboratory
LC	Limited Configuration
LRF	Lateral Range Function
MVT	Model Validation Team
NAVFAC	Naval Facilities Engineering Command
NCSL	Naval Coastal Systems Laboratory
NTS	Naval Torpedo Station
NUSC	Naval Underwater Systems Center
PMR	Pacific Missile Range
PTR	Portable Test Range
PVC	Polyvinyl chloride
ROMS	Remote Optical Mapping System
RUWS	Remote Unmanned Work System
SLS	Side-Looking Sonar
SSP	Semisubmerged Platform
TRANSDEC	Transducer Evaluation Center
TRB	Torpedo Recovery Boat

SUMMARY

OBJECTIVE

Develop techniques by which underwater search sensors can be quantitatively evaluated in actual ocean environments.

RESULTS

The Portable Test Range (PTR) project has evolved into a valuable collection of hardware, experience, and expertise.

The hardware is primarily stored in a self-contained "hut," an air-conditioned, ship-mountable module with space for PTR displays and operators. The most important hardware is a complete Klein Side-Looking Sonar (SLS) system, with fish, stripchart recorder, cable, and depressor vanes. Other items are a microprocessor, various calculators, target and array components, batteries for the Klein and a Mini Ranger Navigation System, and a battery charger.

The experience of the PTR team is documented as fully as possible in this report and in the documents listed in appendix A. This experience includes the process by which methods were developed, and it also includes a significant amount of software that can be made available to others facing similar problems of navigation or data reduction.

The PTR expertise consists of individual skills and knowledge gained by using the Side-Looking Sonar, Acoustic Transponder Navigation System, Mini Ranger, and by rigging and deploying the target arrays. This expertise resulted in members of the PTR team being used or consulted in various non-PTR efforts, including the Wake Island search for a downed C-130 aircraft, a search and recovery of lost experimental hardware off Mission Beach, and SUBDEVGRUONE experimental operations.

RECOMMENDATIONS

Under present funding constraints it is not feasible to continue comprehensive search sensor evaluation in support of the Advanced Unmanned Search System (AUSS) model. Placing the Portable Test Range on the shelf, however, would be wasting the potential asset the PTR team has built. The PTR task team recommends that the system be readied for standby operation in the following manner:

- Make the Portable Test Range completely operational by completing and testing the microprocessor/Mini Ranger navigation system.
- Acquire a Mini Ranger, or its equivalent, to make the PTR search system stand alone and ready.
- Acquire a winch with slip rings for deep search.

CONTENTS

INTRODUCTION

BACKGROUND

The Naval Ocean Systems Center (NOSC) has developed an extensive computer model for predicting the effectiveness of search systems and techniques as affected by various parameters of target and environment. This model,[1] the heart of the Advanced Unmanned Search System (AUSS) project,[2] is the result of extensive investment of time, manpower, and financial resources. There exists a need for search data to evaluate the AUSS computer model; particularly, to provide a totally independent comparison by which the assumptions of the model can be validated, and, where necessary, improved. The Advanced Unmanned Search System Portable Test Range (AUSS PTR) task team was formed to devise methods of acquiring empirical ocean data on the performance of various search sensors, as a function of environmental and operational parameters.

APPROACH

In the initial phase of the PTR effort an investigation was performed to assess capabilities and deficiencies of existing sonar search technology. (See P39 and P40, page A-1.) As a result of this investigation, the following goals were selected for the first-year PTR effort:

a. Design meaningful sensor tests.

b. Determine the number and scope of such tests, which are necessary to assess the effects of environmental and operational parameters.

c. Collect data.

d. Analyze the collected data for comparison with and/or inclusion in the AUSS computer model.

Preliminary PTR concept studies (see V2, V3, V4, page A-1; V8, page A-2, appendix A) rejected any type of portable bottom installation for translation of search sensors. Such an installation would be extremely costly, would introduce unnatural operating conditions, and would not eliminate a need for a sensor navigation system. It was concluded that the only practical means of sensor translation, for the foreseeable future, would be towing from the surface. The task of the PTR team would be to place meaningful targets in known locations, in various environments, and then to tow a sensor through the target field. Data would be collected on the number of detections and detection failures, as a function of sensor type and operational variables (velocity, depth, range, height, attitude, etc.), and also as a function of relevant environmental parameters (water clarity, background noise, bottom material and roughness, magnetic background, etc.). These data would then be reduced and presented in a format appropriate for comparison with AUSS model predictions.

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1. Naval Ocean Systems Center Technical Report, Advanced Unmanned Search System (AUSS) Deep Ocean Floor Search Performance Computer Model Executive Summary, by T. J. Keil (in preparation).

2. Naval Ocean Systems Center Program Summary, Advanced Unmanned Search System (AUSS), NOSC Work Unit 521-765105, -06, of 1 August 1977.

Side-Looking Sonar (SLS), as the basic tool of underwater search, was selected for initial investigation. Emphasis was placed on areas with smooth sandy bottoms. The variables involved were thereby reduced to a manageable number.

Submarine Development Group One (SUBDEVGRUONE) was acquiring a Klein Associates SLS system and it was hoped that it could be used for PTR tests. (See V53, page A-7.) It was also hoped that PTR tests could be "piggybacked" with the Remote Unmanned Work System (RUWS) checkouts. The RUWS system would have provided a means of target deployment, inspection, and navigation.

Because of continual disappointments in planned "piggyback" operations (see V17, V23, page A-3; V29, page A-4), the PTR performed initial sonar tests using two rented systems (Klein Associates model 402 SLS, and EG&G model Mark 1B SLS). In order to minimize the cost and logistics of subsequent tests, a Klein Associates 402 SLS system was purchased.

A PORTABLE TEST RANGE

SITE SELECTION

The location for a PTR operation must possess the desired environmental characteristics, and it must also meet certain practical operational criteria. Relevant environmental parameters, in the case of side-looking sonar evaluations, include water depth, background noise, false targets, and bottom type (material, roughness, and slope). Operational considerations require that the site be as near as possible to a convenient port (especially NOSC, San Diego); free of interfering ship, submarine, or pleasure craft traffic; and not subject to excessive rough weather. Furthermore, line-of-sight contact with landbased radar transponder sites provides an invaluable simplification to the problem of navigation.

Navigation charts, available from the U.S. Coast and Geodetic Survey, enable potential sites to be identified and provide crude bathymetry information. Weather reports are available from the Fleet Numerical Weather Center at Monterey, California. Detailed bathymetry is often available from universities or government agencies having familiarity with the particular area. Information on bottom sediment types from over 40,000 locations is computerized and stored in the World Ocean Sediment Data Bank of the Scripps Institution of Oceanography of the University of California, San Diego (see V11, page A-2).

Local experts were consulted for information about ship traffic, submerged obstructions, and submarine transits. Scheduling groups, the U.S. Coast Guard, and U.S. Marine Amphibious Forces were consulted to minimize danger of interference with other operations.

Potential navigation transponder sites were inspected to ascertain their suitability, security, and availability. It was always desirable to have the two transponder sites located so that the interrogating vessel could pass directly between them, thereby determining their separation.

As a final step in site selection, each site was surveyed. Ship's fathometer assured proper depth and slope. Inspection was performed by divers, or by remote television where possible, and sediment samples taken. In deep locations, the inspection was by Side-Looking Sonar (SLS). Site selection was considered complete only after such surveys verified the bottom was smooth, sandy, and free of false sonar targets.

TARGET SELECTION

A "meaningful" test target is one from which SLS performance can be quantitatively measured. To be meaningful, a test target must be marginally detectable; probability of detection must be measured by the ratio of number of actual detections to number of detection opportunities. To be detectable at all, a target must reflect significantly more sound than its environment (or, alternatively, significantly less sound than its environment). To be recognized, or separated from false targets, a target must be extremely detectable, and therefore no longer meaningful as a test target; or it must possess distinguishing characteristics other than target strength, such as significant size, unique shape, or unusual "shadow" (region of no echo). But recognizable shape or shadow require resolvable size. Another distinguishing characteristic of a marginal target could be a marker, either mathematical or physically real, indicating its exact location among false targets. Therefore, the test targets must be marginally detectable, and must either be large or be marked to be recognizable.

Actually, in order to determine the number of detection opportunities, the location of each target must be known: a particular target is detected only if it is seen in the indicated location on the sonogram. Thus, in practice, *all* targets must be marked in some way, so there remain no practical reasons to use large test targets.

It is essential that the characteristic which makes the target marginal, its target strength, be quantifiable. This also makes omnidirectionality highly desirable; detectability should not be a function of target orientation with respect to the sensor. There are only two types of omnidirectional acoustic targets: transducers (pingers or transponders) and fluid-filled spheres. Calibrated transponders are not readily available, and would be difficult to recover and costly if lost. Spheres, being relatively inexpensive, can be considered expendable.

By proper selection of the internal fluid, spheres can be "focused" (see V55, page A-7) so that sound waves are concentrated at a point on the back surface of the sphere, and reflected directly back toward the source. The result is an extremely high target strength for the sphere size. The fluid usually used, a mixture of carbon tetrachloride and fluorocarbon, is potentially hazardous, has varying sonic impedance with pressure and temperature, and is costly. Plain sea water, on the other hand, is readily available and does not cause changes in target strength with varying environmental conditions.

Calculations based on standard sonar equations and empirical measurements (see V41, page A-5) indicated that, for smooth sandy bottoms and typical SLS characteristics, water-filled spheres somewhat less than a foot in diameter would be marginally detectable. A survey of potential vendors led to the selection of stainless steel spheres, 7 and 14 inches in

diameter, drilled to fill with sea water. Calibration tests (see V21, page A-3) at the NOSC Transducer Evaluation Center (TRANSDEC) verified that the target strength of these spheres is predictable and omnidirectional, despite the fill holes and the circumferential weld. Figure 1 is the beam pattern of a PTR 14-inch sphere.

The tests also revealed a totally unexpected phenomenon: the original return of each sphere was followed by a series of "echoes," apparently due to internal reverberation. Tests with SLS showed that the reverberations of the 14-inch sphere were clearly visible on the sonogram (when the sphere was detectable) and therefore were a distinguishing characteristic, eliminating the recognition problem. The reverberations of the 7-inch spheres were barely resolvable with the EG&G sonar, and not at all with the Klein. The small spheres could be distinguished from false targets only by the previously discussed marking techniques. The 14-inch sphere is apparent in figure 2, which is a sonogram of a test target array. Figure 3 is a pictorial explanation of figure 2. This sonogram was obtained during a sea test (see V35, page A-5) in which several candidate test targets were evaluated. Similar results were obtained in a static test at San Vicente Dam. (See V40, page A-5.)

TARGET ARRAY DEPLOYMENT

The SLS test targets, as explained in a preceding section, are small spheres. The test targets for any other sensor (acoustic, magnetic, optical, nuclear, etc.) would also generally be small objects. In all cases, the exact location of the targets must be marked, and the emplacement should be inspected. Inspection is necessary to assure that the targets are not undetectable as a result of being buried in the mud, drifting away, landing on a false target, etc.

The scheduling and cost of operation of manned and unmanned vehicles made their use impractical for surveying, placement, or inspection. Ideally, the implantment device or "pod" (see V12, page A-2) should be a simple, unpowered, preprogrammed device. The pod would descend to the bottom, rest there while an acoustic location fix was completed, release the target, take pictures of target orientation and surrounding area, measure relevant environmental parameters, and ascend for recovery and redeployment. The pod sequence is illustrated in figure 4. Hardware development on this scale, however, was not possible during this year.

The concept of a free-falling linear array was developed as an alternative to any type of implantment device or vehicle (see V16 and V20, page A-3). By designing the array to fall rapidly, its approximate location can be determined by surface navigation, and its exact location on the sonograms can be marked by one or more triplane sonar markers. (See V22, page A-3.) By alternating strong targets with weaker ones, equally spaced, the exact location of each can be interpolated or extrapolated on the sonogram. In a sense, all detected targets aid in marking the location of any undetected ones. Even if no test target on a particular array is detected, the triplane marker indicates whether the array was in range and whether its targets should be counted as a set of detection opportunities.

Theoretically, surface navigation is just a convenience to maximize the probability that the sensor will indeed pass within detection range of an array on a particular test run.

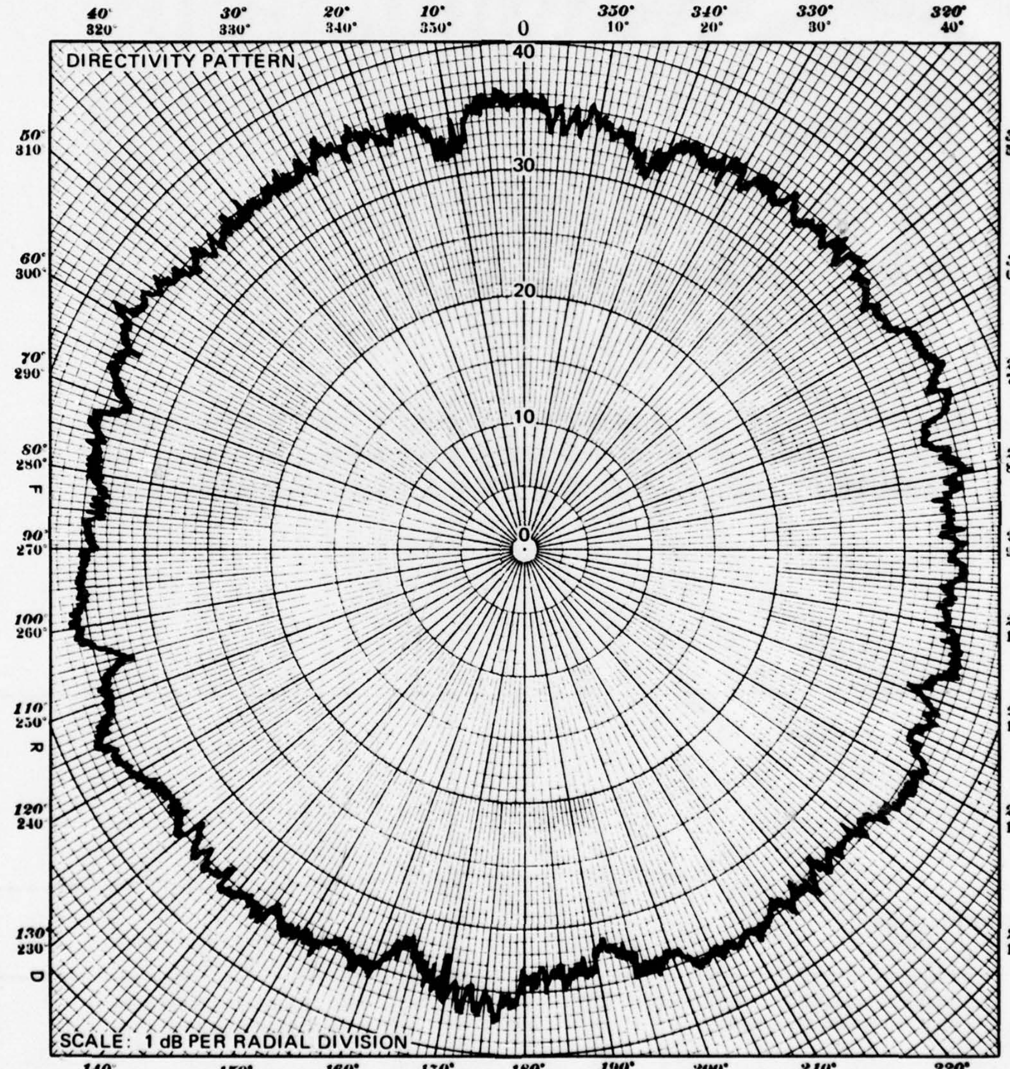

Figure 1. Beam pattern of portable test range [illegible]4-inch sphere.

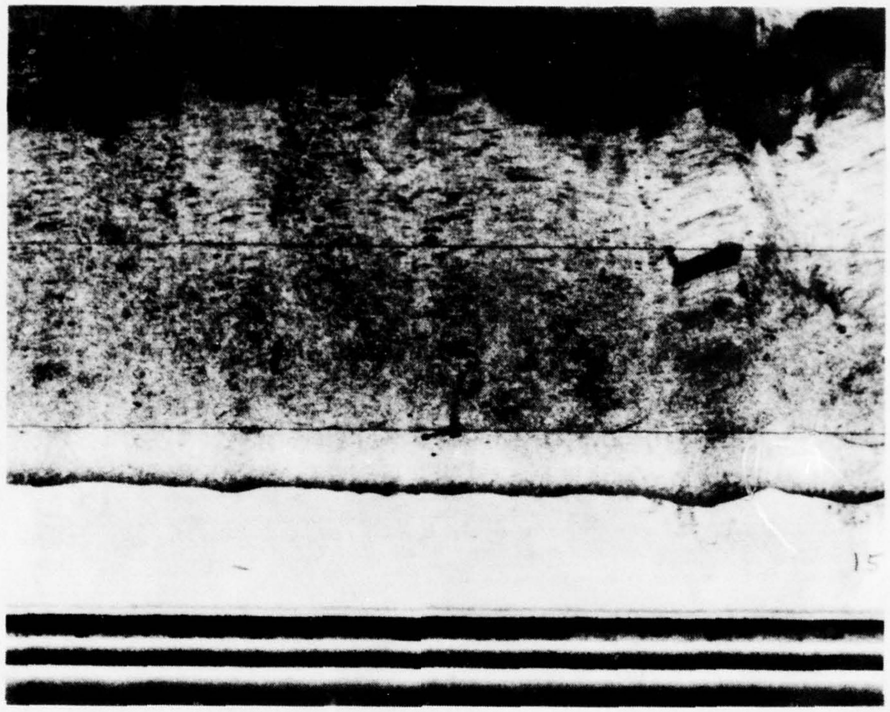

Figure 2. Sonogram of test target array.

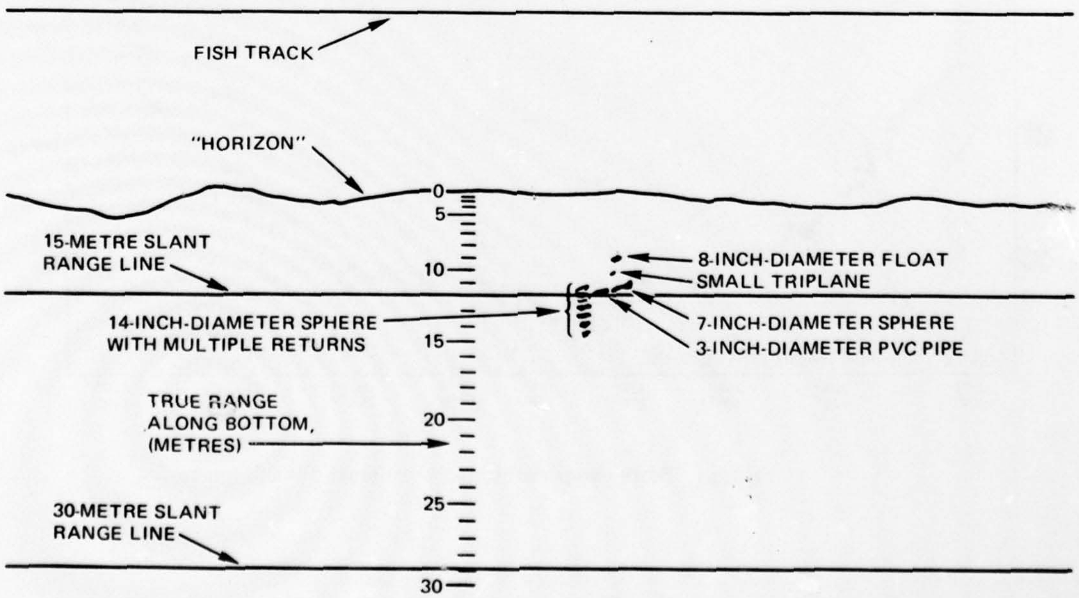

Figure 3. Interpretation of target array sonogram.

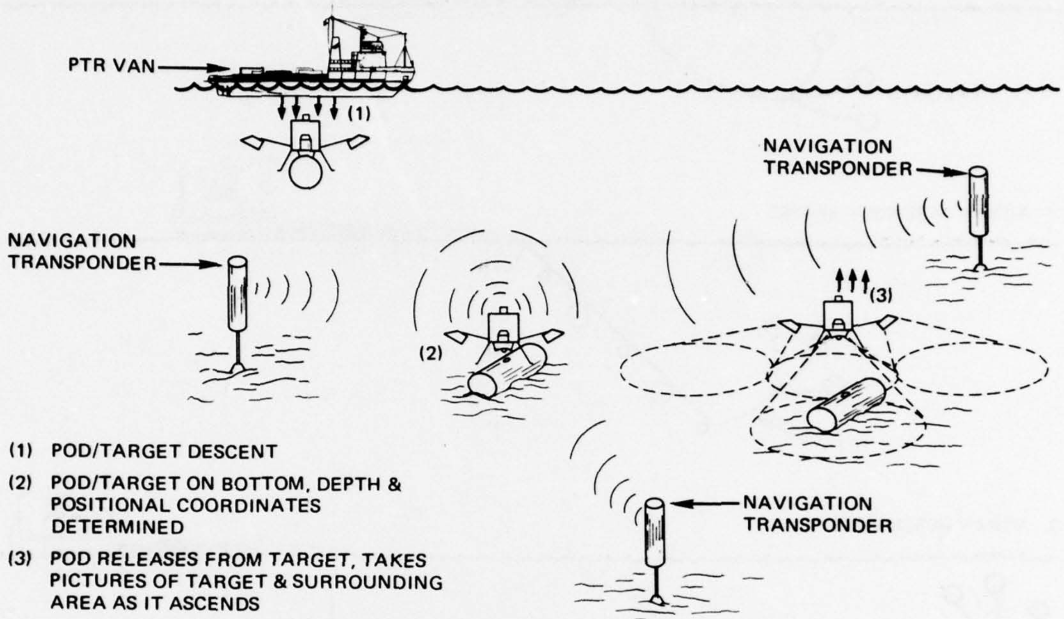

Figure 4. Portable test range (PTR) pod operation.

In practice, however, triplanes even as large as two feet on a side, were not always distinguishable from false targets. In shallow water tests, surface buoys were used to mark the arrays and guide the pilot in making his runs, but these surface markers were short-lived, seldom remaining overnight. In practice, a real-time navigation system became indispensable to PTR operations.

Polyvinyl chloride (PVC) pipe was chosen as the means of assuring the linearity of the test arrays. The pipe was 4-inch schedule 80 cut to 10-foot lengths and easily assembled to any length. Each array would be assembled section by section, floating horizontally. A heavy descent weight would be added to the end of the array and lowered until the array floated nearly vertically. The weight would be released, sinking the array to the bottom. The array itself, still vertical and still buoyant, would not yet strike the bottom. Three floats on the top would be released sequentially by corrosive links, causing the array to settle to the bottom and slowly topple to the desired horizontal position. Figure 5 illustrates this deployment sequence.

One 100-foot array was deployed in shallow water to test the deployment method. Divers then inspected it to assure its integrity and linearity. Several small, 10-foot arrays, using one 7-inch and one 14-inch sphere were then tested to check their detectability. Figure 6 is a drawing depicting one such 10-foot array. With both the deployment mode and the target choice confirmed, the final array configuration was chosen: 30 feet of PVC

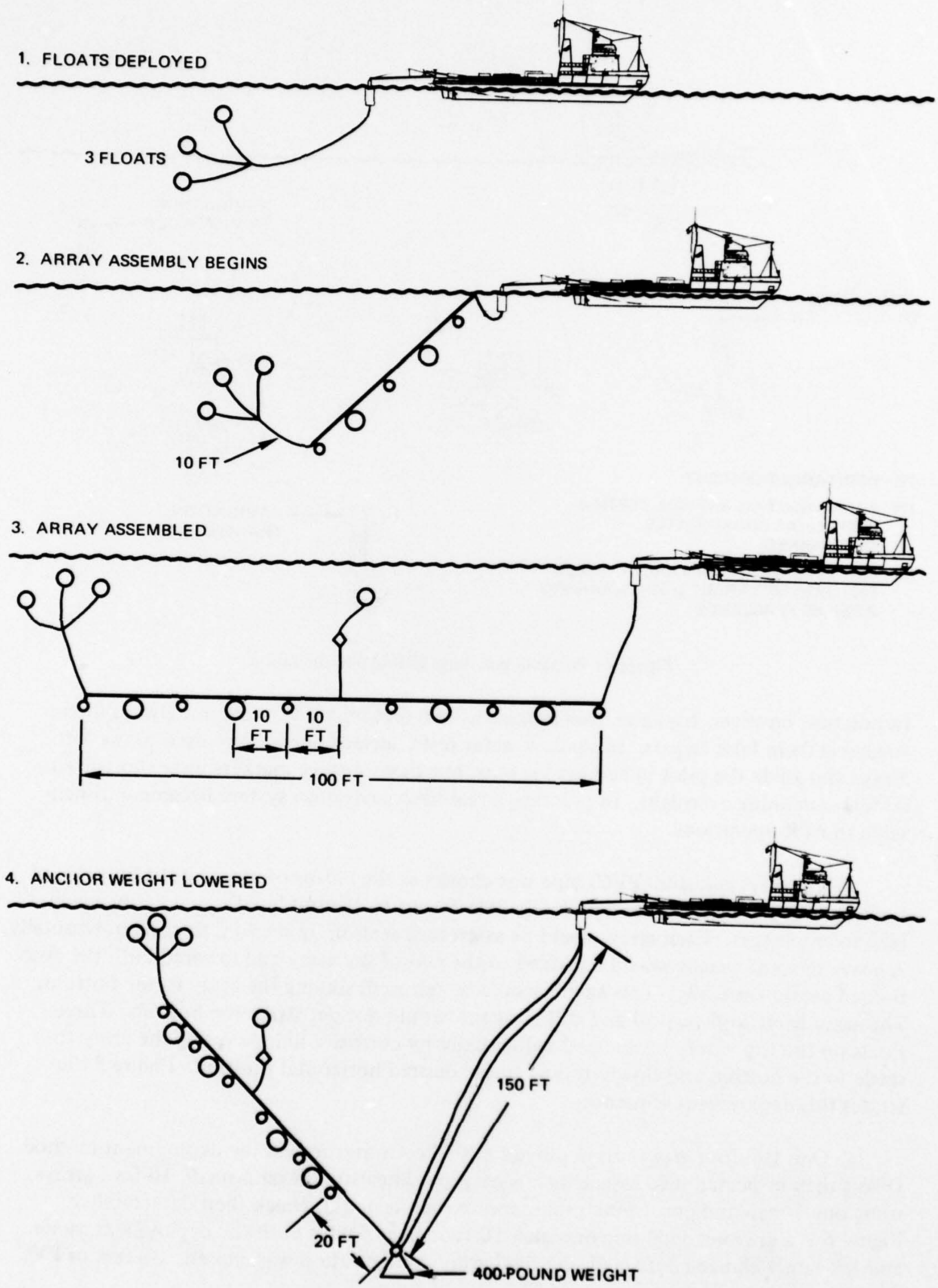

Figure 5. Deployment of test target array in deep water.

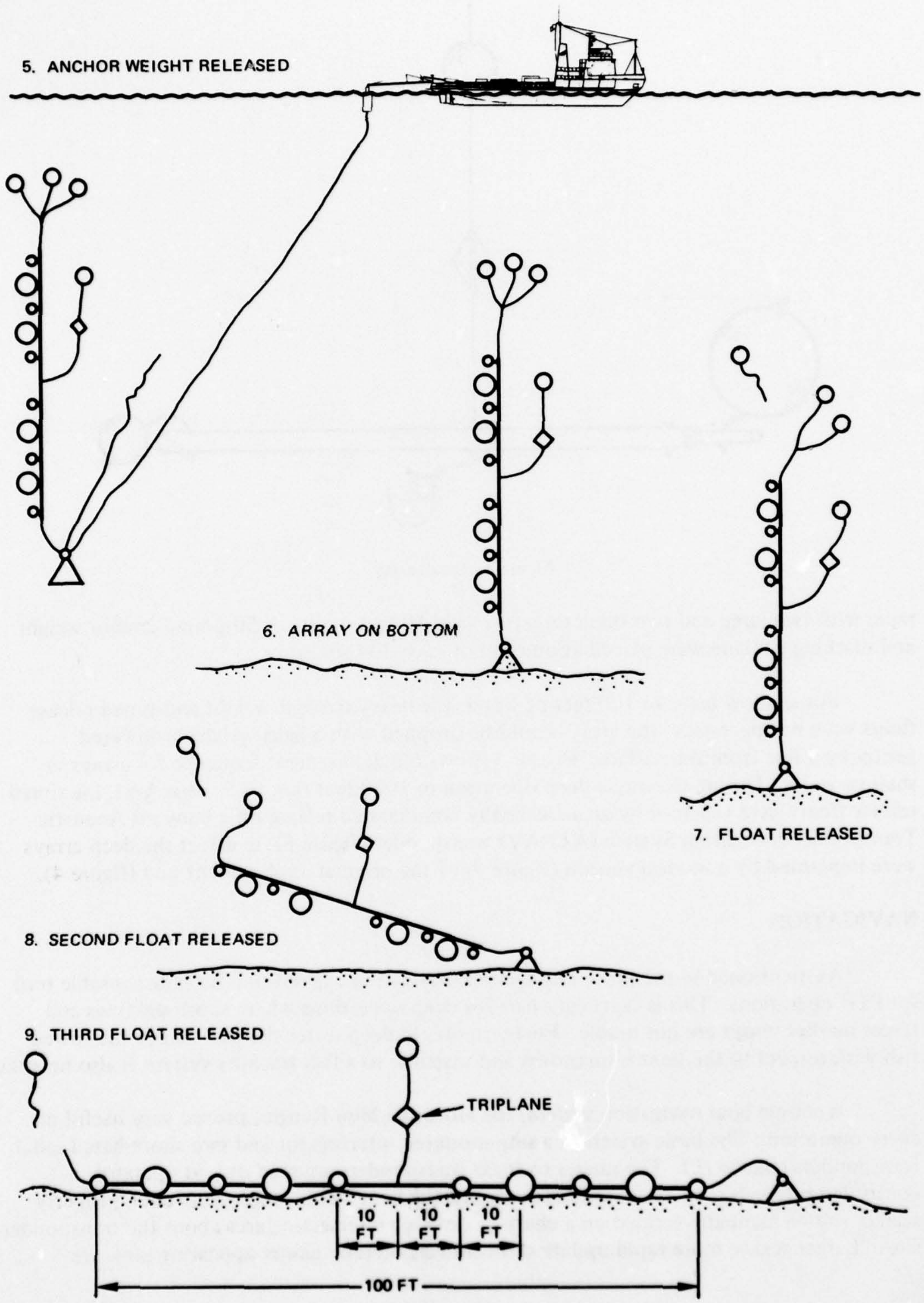

Figure 5. (Continued)

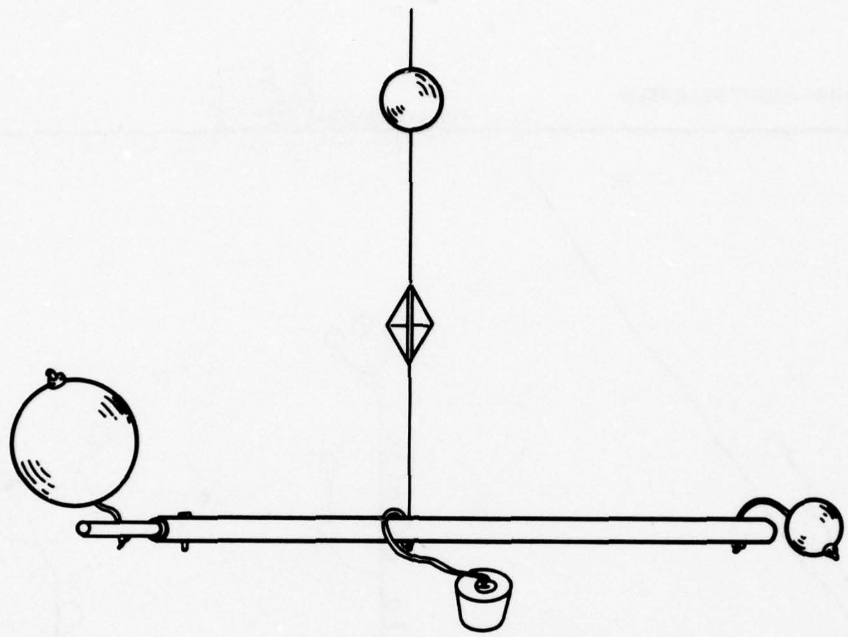

Figure 6. Small array.

pipe, with two large and two small targets spaced 10 feet apart. A 50-pound anchor weight and marking triplane were placed at one end of each 30-foot array.

For shallow tests, in 100 feet of water, the heavy descent weight and timed release floats were not necessary; the arrays could be dropped with a light weight or lowered gently by a line from the surface. Figure 7 shows the deployment sequence for arrays in shallow water. During the single deep operation in 1000 feet (see V69, page A-8), the timed release floats were replaced by an acoustically commanded release on a buoyant Acoustic Transponder Navigation System (ATNAV) transponder (figure 8); in effect the deep arrays were implanted by a modest version (figure 9) of the original implantment pod (figure 4).

NAVIGATION

As mentioned in the preceding section, navigation capability is an indispensable tool for PTR operations. This is especially true for deep operations where shore sightings and target marker buoys are not usable. Furthermore, in deep water the position of the towed fish with respect to the boat is unknown and variable, so a fish tracking system is also necessary.

A simple boat navigation system, the Motorola Mini Ranger, proved very useful on every operation. The basic system is a ship-mounted interrogator and two shore-based radar transponders (figure 10). The ranges to these transponders are read out, at operator-controlled intervals (one to six seconds), aboard the boat. This range-range data, properly scaled, can be manually scribed on a chart by drawing intersecting arcs about the transponder sites. Larger scales, more rapid update rates, and a generally neater appearing plot, are

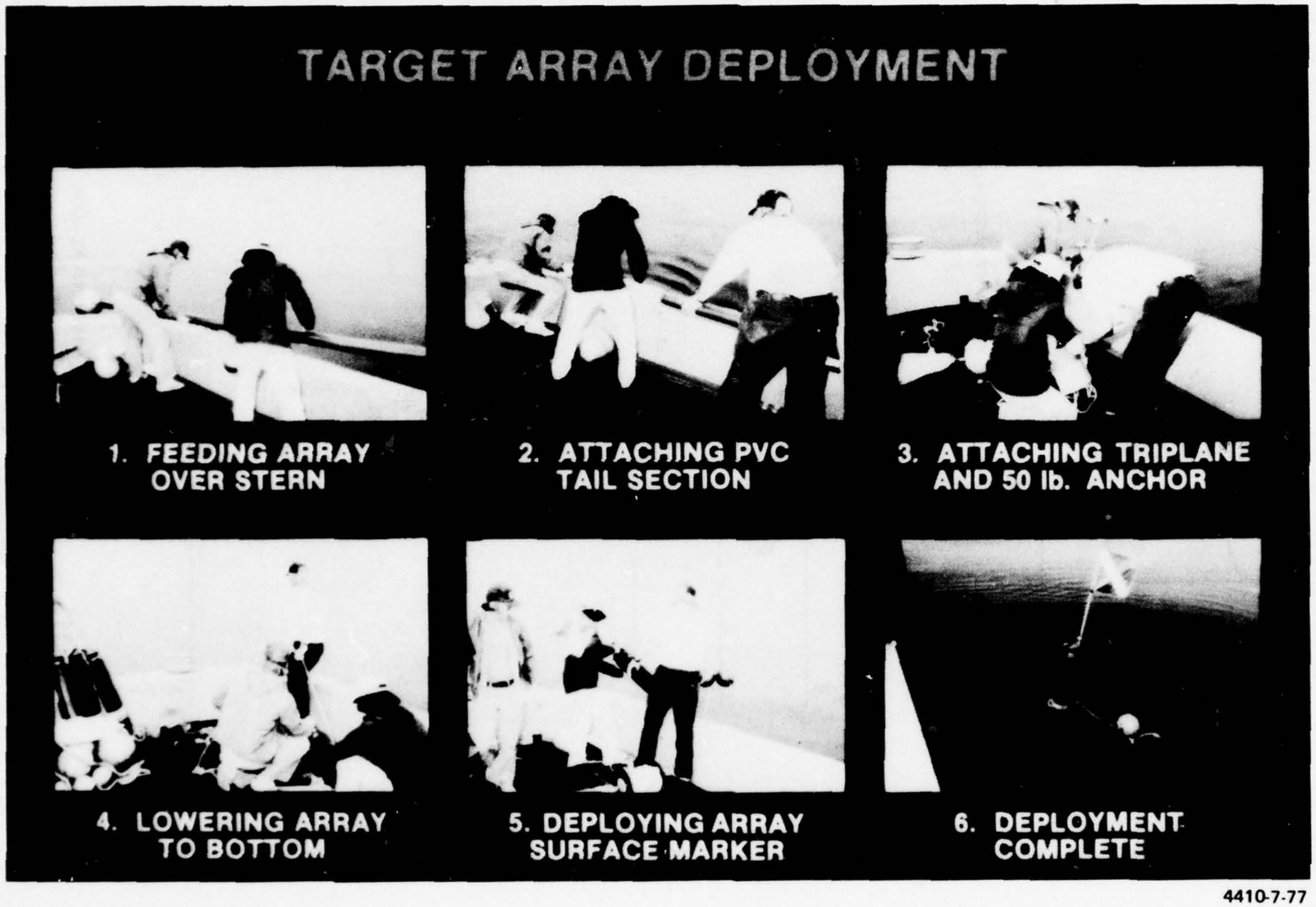

Figure 7. Deployment sequence for shallow water.

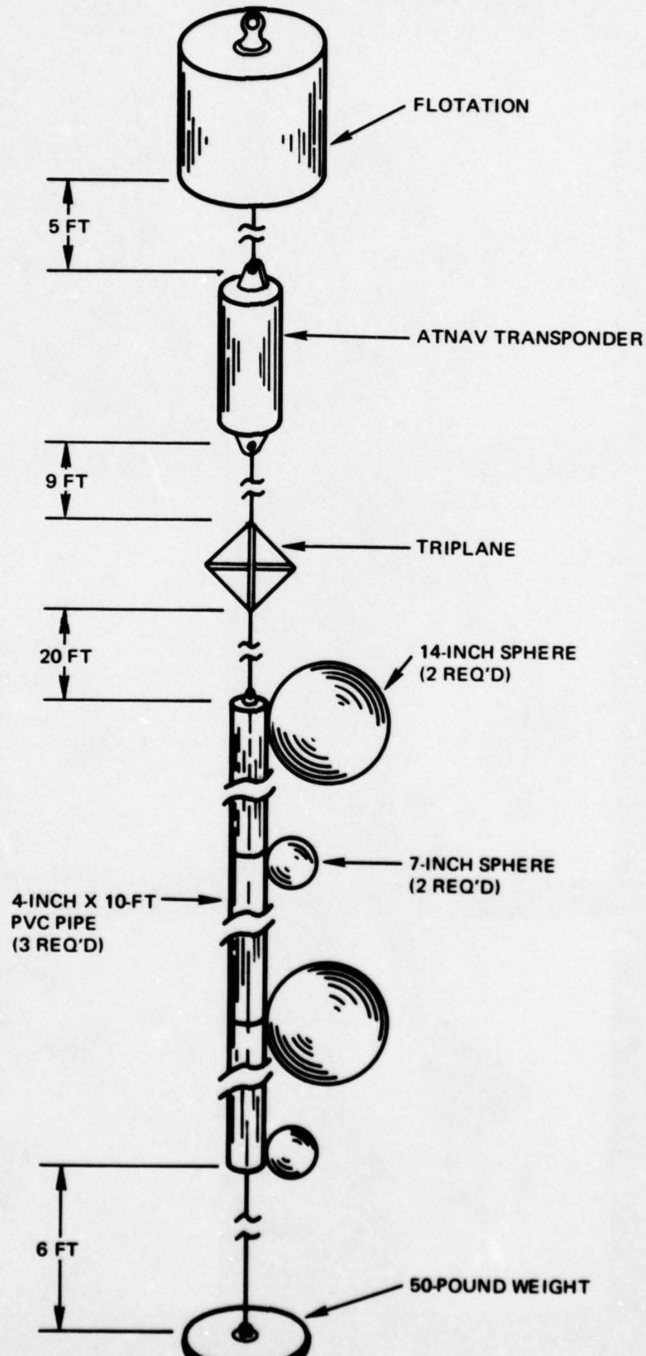

Figure 8. Array for deep test.

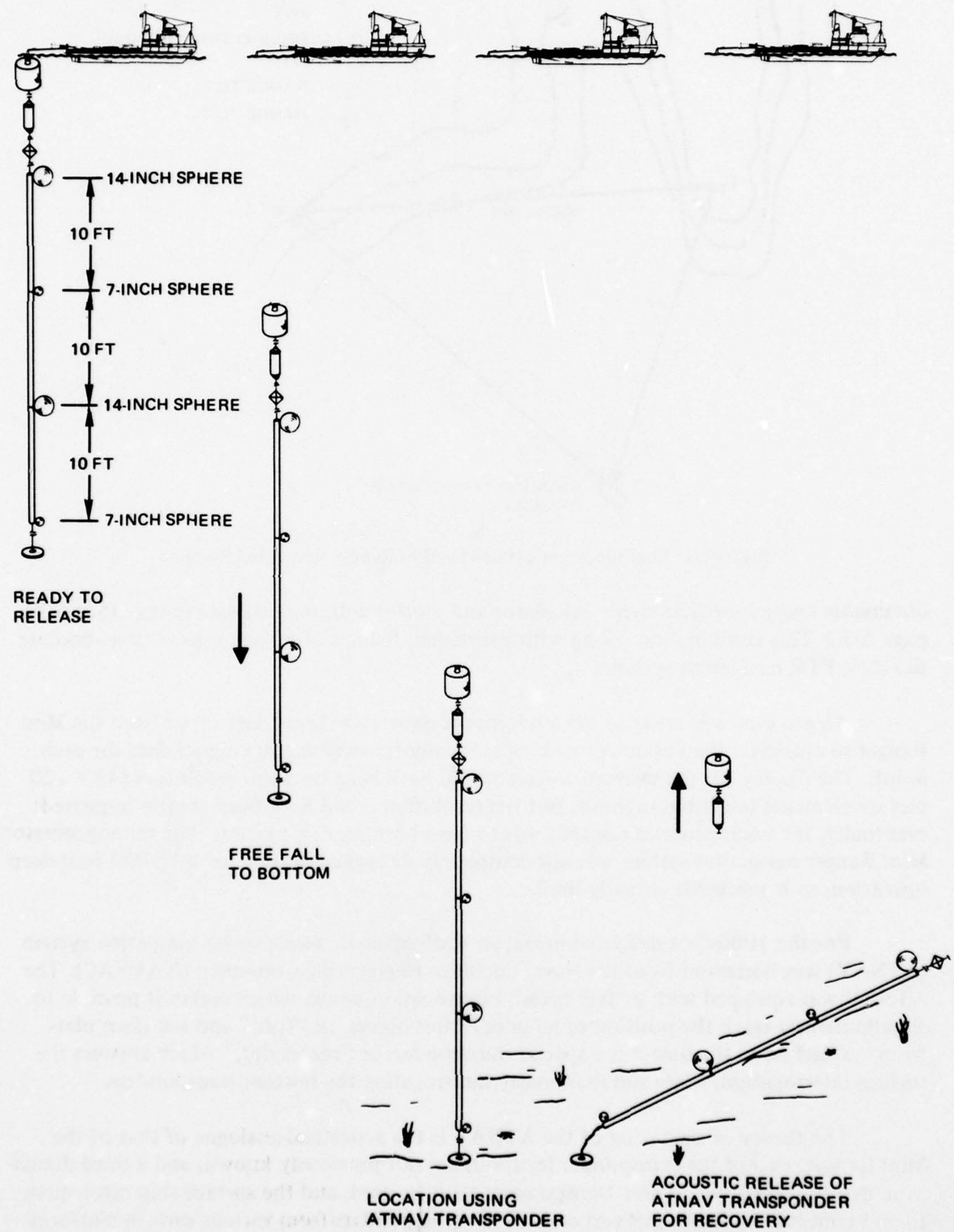

Figure 9. Target array deployment and location technique for deep test.

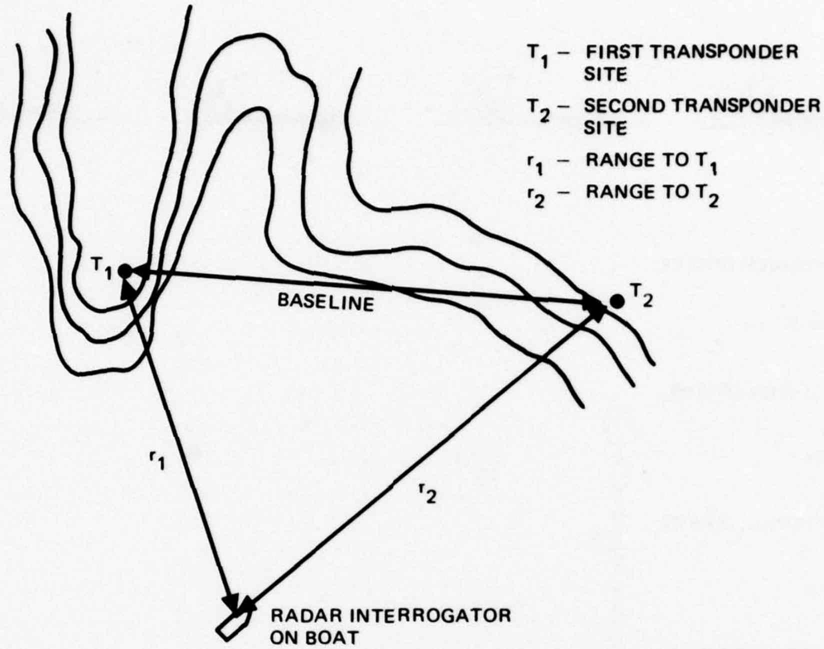

Figure 10. Boat's location defined by Mini Ranger Navigation System.

obtainable using a programmable calculator and plotter with manual data entry. (See V39, page A-5.) This combination, along with permanent listings of range-range vs time, became the basic PTR navigation system.

An attempt was made to use a microprocessor with direct data input from the Mini Ranger to eliminate the tedious process of manually transcribing the digital data for each point. The display for the microprocessor would have been on a low resolution (48 X 120 picture element) television monitor, but the resolution could have been greatly improved: eventually, the microprocessor output was to have been an X-Y plotter. The microprocessor/ Mini Ranger navigation system was not completely debugged in time for the 1000-foot-deep operation, so it was never actually used.

For the 1000-foot-deep operation, an AMF acoustic transponder navigation system (ATNAV) was borrowed from the Naval Facilities Engineering Command (NAVFAC). The ATNAV was equipped with a "fish cycle" interrogation mode, which makes it possible to simultaneously track the position of an underwater object, or "fish," and a surface platform. Attached to the object is a special transponder, or "responder," which answers the surface interrogation, while simultaneously interrogating the bottom transponders.

The theory of operation of the ATNAV is the acoustical analogue of that of the Mini Ranger, except the transponder locations are not previously known, and a third dimension, depth, is involved. Three transponders must be used, and the surface ship must survey them by measuring slant ranges to each of the transponders from various surface platform positions (survey points). A PDP-11 mini-computer solves a set of simultaneous equations

to obtain assumed transponder locations for best fit with the accumulated survey data. Once surveying is completed, the ATNAV system is capable of performing the navigation operations.

The operation for obtaining surface platform/fish navigation points begins with interrogation of the bottom transponders from the surface platform. Each transponder replies individually to the ATNAV shipboard equipment which determines their slant ranges from the ship. Immediately afterward, another interrogation is sent to the responder on the fish. The reply from this responder does two things. First, it permits determination of the slant range from the fish to the surface platform. Second, the same reply interrogates the bottom transponders so that the total distance from the surface platform to the fish, to each of the transponders, and back to the surface platform can be ascertained. This is called the fish cycle. This range data is used to determine the positions of both the surface platform and the fish relative to the individual bottom transponders. The resulting track information is displayed on a plotter and printed out by a teletype for a permanent record. Figure 11 is a diagramatic representation of the ATNAV theory of operation. Reference 3 describes in detail the ATNAV system.

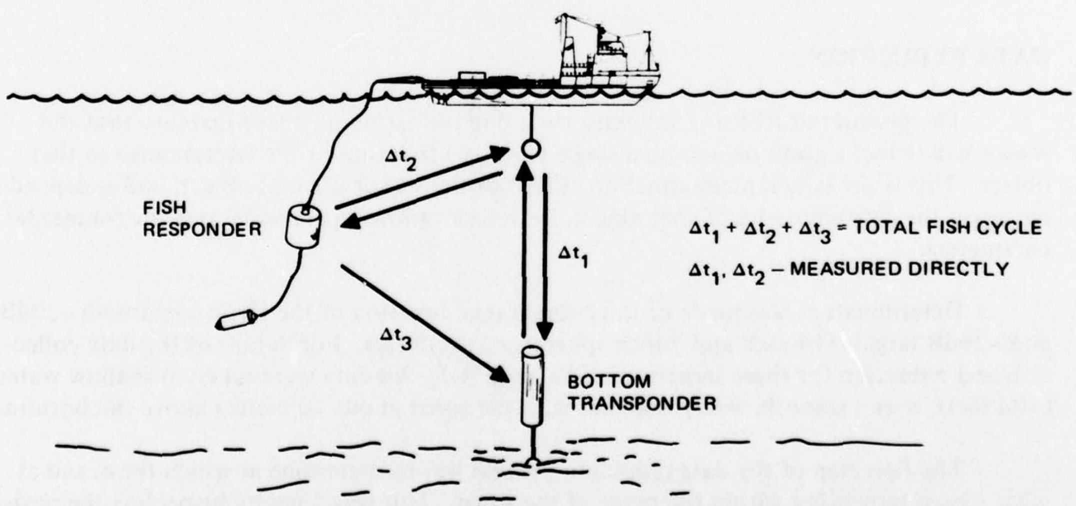

Figure 11. Boat cycle and fish cycle of Acoustic Transponder Navigation System.

The accuracy of the ATNAV was judged by comparison with the Mini Ranger and by correlation with the sonograms. The mean error in ship's position between the navigation systems, based on eleven of the ATNAV survey points, was 11 metres. (See V60, page A-7.) Approximately one-half of this error is accounted for by the fact that the interrogators for

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3. AMF Sea-Link Manual Acoustic Transponder Navigation System (ATNAV), AMF Electrical Products Development Division, Herndon, Virginia.

the two systems were separated by 6 metres. The targets seen on the sonograms were, in the worst case, about 20 metres from the lateral range predicted by the ATNAV.

On the scale of 200 metres per inch, and an update rate of 45 seconds or 60 seconds, the ATNAV plotter was an excellent tool for real-time navigation and for data reduction. Figure 12 is an example of an ATNAV plot showing ship and fish position during deep operations. Certain unexplained irregularities (see V69, page A-8) did occur in the listed ATNAV coordinates, especially in fish depth readings, but they did not affect the PTR operations. Also, these irregularities seem to have been peculiar to the particular operation with the particular ATNAV, so should not recur in a similar application.

From the ATNAV plots, it is apparent that surface navigation was not adequate for determining fish position in deep water; the fish lagged several hundred metres behind the surface platform and tracked several 10's of metres to the side. The targets, however, were well located by surface navigation. (See V64, page A-8.) Ideally, a ship-mounted fish locator, used in conjunction with the Mini Ranger and ship's compass, could be used, and would eliminate the need for the ATNAV transponder implantment, survey, and PDP-11 minicomputer. A program (see V65, page A-8) was prepared by the PTR team for use with the HP-9100 calculator and plotter and a modified AMF301 transponder locator. This system was tested by SUBDEVGRUONE during SLS tow tests, but the AMF301 system failed to give sufficiently accurate bearing information on their towed fish.

DATA REDUCTION

The product of PTR for any sensor is a determination of the probability that the sensor will detect a given object, on a single pass, as a function of the lateral range to that object. This is the lateral range function (LRF) of the sensor for that object, and is dependent upon the characteristics of that object, as well as various operational and environmental parameters.

Determination was made of the lateral range function of the Klein sonar with −20dB and −26dB targets (14-inch and 7-inch spheres, respectively). For details of the data collection and reduction for these targets see V42, page A-5. All data were taken in shallow water (100 feet), over a smooth, sandy bottom, with the sonar about 10 metres above the bottom.

The first step of the data reduction process was to determine at which times and at what ranges targets lay within the range of the sonar. This was done by inspecting the navigation plot showing the location of the targets and fish during each run. (In shallow water the fish was assumed directly behind the boat's position as determined by Mini Ranger.) The sonograms were then inspected to determine which targets were detectable. All detections and detection failures were tabulated as to range to target at time of passage, as indicated by the sonogram slant range and/or the navigation chart. These data were all converted to true lateral range.

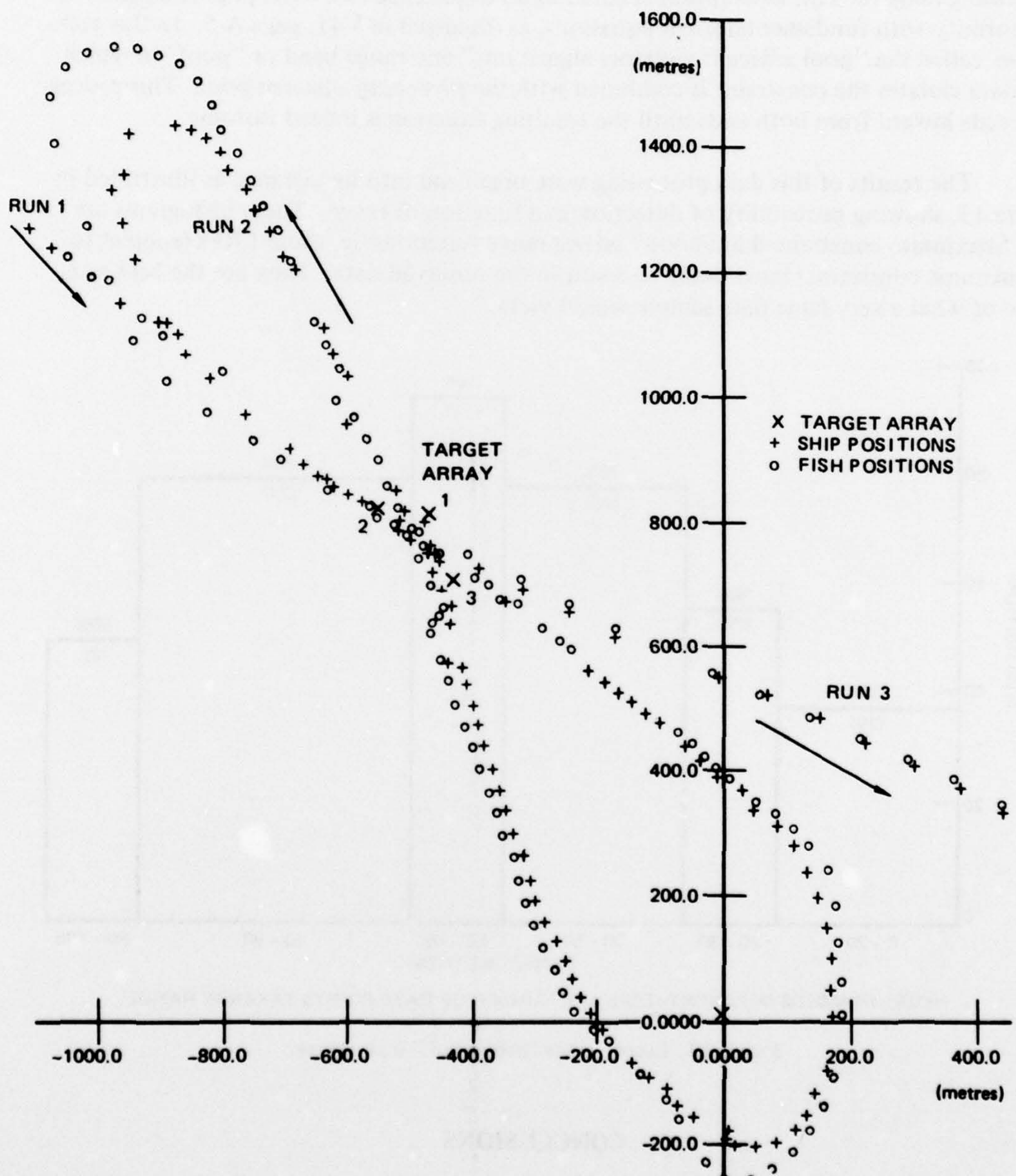

Figure 12. Sample Acoustic Transponder Navigation System (ATNAV) plot.

The tabulated data were then organized into frequency tables showing ratio of number of detections to number of detection opportunities in each 10-metre lateral range band. Finally, the information on the frequency tables was manipulated by a special estimation technique, to conform to the assumption that the lateral range function (LRF) must be isotonic (rising monotonically to a peak at some range, and decreasing monotonically at increasing ranges). This assumption is based upon experience (see V62, page A-8) and is in conformity with fundamental sonar equations, as discussed in V41, page A-5. In this technique, called the "pool adjacent violators algorithms" any range band or "pool" in which the data violates the constraint is combined with the preceding adjacent pool. This process proceeds inward from both ends until the resulting function is indeed isotonic.

The results of this data processing were organized into histograms, as illustrated in figure 13, showing probability of detection as a function of range. These histograms are the "maximum constrained liklihood" lateral range functions; ie, those LRFs (subject to the isotonic constraint) most likely to result in the observed data. They are the best estimate of what a very large data sample would yield.

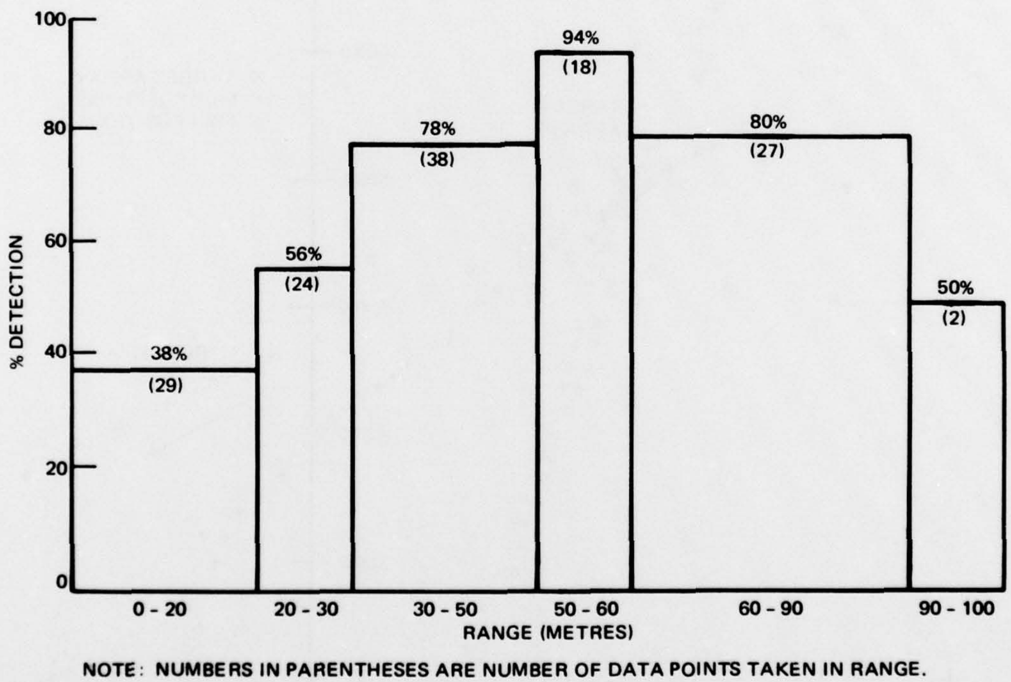

Figure 13. Lateral range function of 7-inch sphere.

CONCLUSIONS

The PTR has evolved into a valuable collection of hardware, experience, and expertise.

The hardware is primarily stored in a self-contained "hut," an air-conditioned, ship-mountable module with space for PTR displays and operators. The most important hardware is a complete Klein SLS system, with fish, stripchart recorder, cable, and depressor vanes.

Other items are a microprocessor, various calculators, target and array components, batteries for the Klein and Mini Ranger, and a battery charger.

The experience of the PTR team is documented as fully as possible in this report and in the documents listed in Appendix A. This experience includes the process by which methods were developed, and it includes a significant amount of software which can be made available to others facing similar problems of navigation or data reduction.

The PTR expertise consists of individual skills and knowledge gained by using the SLS, ATNAV, Mini Ranger, and by rigging and deploying the target arrays. This expertise resulted in members of the PTR team being used or consulted in various non-PTR efforts, including the Wake Island search for a downed C-130 aircraft (see V62, page A-8), a search for and recovery of lost experimental hardware off Mission Beach, and SUBDEVGRUONE experimental operations. (See V31, page A-4.)

RECOMMENDATIONS

The recommendations for PTR are dependent upon the future level of effort, of which there are three possibilities:

(1) Decommission PTR; cease all funding and effort.

(2) Place PTR on standby; maintain hardware, experience, and expertise for occasional sensor evaluation or actual search.

(3) Continue PTR; evaluate sensors under various operational and environmental conditions.

If the PTR is to be decommissioned, declare the hardware surplus and make it available for NOSC range operations. Storage would be a waste of an asset that can be used now in search and surveys. Passage of time would result in degradation of some components (eg, batteries) and in dispersal of the system components. Some components, like the microprocessor, could grow obsolete without having been used. If this alternative is chosen, the team expertise would also be wasted.

If the PTR is to be placed on standby, first make it completely operational while the expertise is still available. Specifically, complete and test the microprocessor/Mini Ranger navigation system. Acquire a Mini Ranger or equivalent to make the PTR search system stand alone and ready. Acquire a winch with slip rings for deep search.

A completely active PTR, not presently planned or funded, would require all the items listed in the previous paragraph. In addition, the fish tow stability should be improved so that SLS data can be collected at increased ranges and on rough bottoms. A ship-mounted fish locator should be investigated to eliminate the need for an ATNAV in deep operations. An implantment pod should be developed. Magnetometer or Remote Optical Mapping System (ROMS) (see V13, page A-2) evaluations could then be done with PTR.

Under present funding constraints it is not feasible to continue comprehensive search sensor evaluation in support of the AUSS model. Placing PTR on the shelf, however, would be wasting the potential asset the PTR team has built. The PTR task team recommends that the system be readied for standby operation.

APPENDIX A
ADDITIONAL SOURCES OF INFORMATION, PORTABLE TEST RANGE

V1 "Organization of Portable Test Range" by J. M. Walton, NOSC memo 6512-98 of 24 May 1976

Definition of and plans for a Portable Test Range. Emphasis to be on ADOSS as search sensor. Design concept to be developed in FY 7T.

P39 "East-Coast Portable Test Range (PTR) Trip Report (14–18 June 1976)" by J. M. Walton and M. Kono of 16 Jul 1976

Summary of discussions with personnel at NRL, ARL, Woods Hole, NUSC, Chesapeake Instr., NCSL, Westinghouse, and Honeywell. General Subject of SLS tests and operation, navigation, fish stability, free swimmers, and need for PTR.

P40 "West-Coast Portable Test Range (PTR) Trip Report (29 June–9 July 1976)" by J. M. Walton and M. Kono of 20 Jun 1976

Visits with personnel at CEL, APL, NTS, U of H, NUC Hawaii, and PMR, Barking Sands. Subjects of bottom types, implantment, navigation, ADOSS, and cable dynamics.

V2 "PTR 'Ski Lift' Line Tension" by R. Uhrich, NOSC memo 6512-143 of 29 Jul 1976

Effect of design constraint on line tension and sheave diameter (580 ft. minimum).

V3 "Relative Merits of PTR Concepts" by R. Uhrich, NOSC memo 6512-144 of 29 Jul 1976

Alternative sensor translators discussed relevant to development effort, difficulty of placement and operation, and impact on technology.

V4 "Lateral Drift of 6000 ft. Underwater Cableway as a Function of Cable Tension (PTR) by R. Uhrich, NOSC memo 6512-149 of 5 Aug 1976

Graph of induced position error of sensor vs tension for 6000 ft. cableway.

V5 "Results of 5 August 1976 Meeting" by J. M. Walton, NOSC memo 6512-154 of 9 Aug 1976

List of major questions related to PTR, work breakdown structure, assignment of areas of responsibility, and bibliography.

V6 "Portable Test Range (PTR): informal status report" by J. M. Walton, NOSC memo 6514-193 of 9 Sep 1976

Discussion of four categories of investigation: (1) System support, (2) Underwater spatial and attitude reference system, (3) Sensor translator, and (4) Target implantment and retrieval.

V7 "Summary of 15 September 1976 PTR Task Team Meeting" by J. M. Walton, NOSC memo 6512-166 of 20 Sep 1976

Emphasis on LC ADOSS and preparation for impending visit of J. Freund. Reject universal implantment device. Introduction of "support clump" inplantment.

V8 "PTR Study Status Report on Sensor Translator" by R. Uhrich, NOSC memo 6512-170 of 24 Sep 1976

Rejection of "universal translator." Suggests alternatives. Emphasis switched from ADOSS to SLS.

V9 "PTR Study Status Report on Target Implantment" by R. Uhrich, NOSC memo 6512-171 of 24 Sep 1976

Discussion of sediment transport and anchoring methods relevant to PTR targets. Alternative implantment concepts lead to "pod" device.

V10 "The Aftermath, New Direction for AUSS Based on Meeting With John Freund, September 30, 1976" by J. M. Walton, NOSC memo 6512-5 of 12 Oct 1976

PTR becomes MVT. "Piggyback" SLS operation with RUWS major objective. Scope of operations drastically reduced to merely determining needs of AUSS model and type of operations to meet needs.

V11 "PTR Site Selection Task" by M. Kono, NOSC memo 6512-4 of 13 Oct 1976

Sources and types of data available on ocean bottom in potential test sites. Recommends cultivation of working relationship with Scripps data bank.

V12 "AUSS Portable Test Range, FY77 Program" by J. M. Walton, NOSC memo 6512-174 of 15 Oct 1976

Detailed presentation of original PTR plan, including sensor translator, attitude reference package, navigation system, and target implantment pod.

V13 "ROMS Transdec Test Plans as they Relate to MVT Tests" by S. Watson, NOSC memo 6511-247 of 1 Nov 1976

Offers test plans as example of the level of preparations necessary for MVT test.

V14 "Borrow/Rental of Equipment for Testing" by S. Watson, NOSC memo 6511-248 of 1 Nov 1976

Points out extreme difficulty historically encountered when test depends on availability and reliability of borrowed instrumentation.

V15 "Trip report Hawaii: 15–22 October 1976" by M. Kono of 11 November 1976

Attempts to arrange for interfacing and support for proposed January SLS test. Facilities concerned included RUWS, SSP, and NAVFAC ATNAV. Preliminary site survey and test procedures discussed.

V16 "SLS Test Target Deployment" by R. Uhrich, NOSC memo 6512-188 of 11 Nov 1976

Discusses alternative modes of deploying linear arrays of spherical targets for Hawaii tests.

V17 "January 1977 MVT Tests Using RUWS" by S. Watson, NOSC memo 6511-263 of 15 Nov 1976

Purpose and procedure of proposed tests in Hawaii. Array to be implanted and surveyed using RUWS and ATNAV; actual SLS tests to be scheduled at later date.

V18 "Status of RUWS OPS" by M. Kono, NOSC memo 6512-202 of 7 Dec 1976

Schedule of RUWS Ops as it impacts MVT "piggyback" plans. Indicates one week available in December and two weeks in January.

V19 "Rental of Motorola Mini Ranger Surface Navigation System" by M. Kono, NOSC memo 6512-204 of 8 Dec 1976

Information relating to shipping, rental, and specifications of Mini Ranger.

V20 "Deployment Procedure of AUSS Sonar Target Array" by M. Kono, NOSC memo 6512-212 of 28 Dec 1976

Introduces concept of PVC pipe for attachment of targets. Smaller spheres to be used, array 100 ft. long to free fall to bottom. Time released floats. No RUWS target placement required.

V21 "Sonar Target Calibrations of 11 January 1977" by R. Uhrich, NOSC memo 6512-08 of 14 Jan 1977

TRANSDEC calibration of 7" and 14" spheres and PVC pipe. Mysterious "multiple returns" from spheres.

V22 "Sonar Marker for Array" by R. Uhrich, NOSC memo 6512-13 of 20 Jan 1977

Explains choice of collapsible 5" triplanes for markers in Hawaii.

V23 "Decision to Discontinue Efforts to "Piggyback" RUWS Operations Until a Later Date" by J. M. Walton, NOSC memo 6512-05 of 11 Jan 1977

New emphasis to be on shallow and deep tests with SUBDEVGRUONE. Necessitated by indefinite delays in RUWS test schedule. Hawaii to be kept in mind.

V24 "First Quarter AUSS PTR Financial Status" by J. M. Walton, NOSC memo 6512-16 of 24 Jan 1977

Listing of total charges to date: $53,836, or 24% of budget.

V25 "Tow Speed of Klein SLS for Test Array" by R. Uhrich, NOSC memo 6512-18 of 28 Jan 1977

Based on AUSS criterion of three "hits" for small targets, and beam pattern of Klein sonar.

V26 "AUSS Portable Test Range Status and Plan" by PTR Team of 31 Jan 1977

Purpose, structure, and plans of PTR with respect to SLS lateral range capabilities for AUSS model. Illustrations of deployment technique for 100-ft. array.

V27 "Side Scan Sonar Test (Test Spec)" by PTR Team of 2 Feb 1977

Test plan to use Klein sonar and experienced operator to survey 10 ft. PVC pipe and steel sphere arrays.

V28 "Simplified Tables for Tow Speed of Klein Sonar" by R. Uhrich, NOSC memo 6512-23 of 3 Feb 1977

Simplified version of V25. Requires slow speed for large range scales.

V29 "Hawaii Trip: 22 Dec 1976 to 7 Jan 1977" by M. Kono, Feb 1977

Mini Ranger site selections and array deployment techniques. Final arrangements for shipping, operations. Indications that RUWS slippages threatened entire "piggy-back" concept. Preliminary investigation of alternatives and compromises.

V30 "Oceanic Data Base Information Exchange Workshop" by J. M. Walton, NOSC memo 6512-34 of 16 Feb 1977

Possible sources of data for test site selection.

V31 "SUBDEVGRUONE Operations" by J. M. Walton, NOSC memo 6512-39 of 25 Feb 1977

Plans for SUBDEVGRUONE sea tests of Klein Side-Looking Sonar.

V32 "Letter to Klein Associates Inc." by J. M. Walton, of 28 Feb 1977

Offers cooperation in and exchange of information in evaluation of Klein. Includes sand-wave sonogram.

V33 "Purchase of a Side Looking Sonar System" by PTR Team, NOSC memo 8612-02 of 2 Mar 1977

Suggests purchase, enumerates problems encountered with borrowed and rented SLS, and discusses advantages to other programs of such an asset.

V34 "Price Breakdown on Klein Side Scan Sonar System" by J. M. Walton, NOSC memo 8612-04 of 8 Mar 1977

Description and prices of recommended components.

V35 "MVT At-Sea Operations of 7 Feb 1977" by MVT Team, NOSC memo 8612-09 of 22 Mar 1977

Comprehensive, illustrated report of result of "dedicated" day of operations, investigating various marked SLS targets. General approach verified; i.e., small spheres on PVC pipe.

V36 "Submission of San Vicente SLS Test Plan" by J. M. Walton, NOSC memo 8612-33 of 3 May 1977

Plans to statistically test sonar resolution and beam pattern, various targets, and recording techniques.

V37 "Portable Test Range (Report to Freund)" by J. M. Walton of 19 May 1977

Purpose, nature, schedule, and cost of past and future SLS tests.

V38 "HP-67 Program to Calculate X-Y Location of Ship Given Range-Range Data" by M. Kono, NOSC memo 8612-51 of 2 Jun 1977

Instructions, designations, and listing of program. Enter range-range; calculator displays X-Y coordinates and ship velocity. HP-67 calculator.

V39 "HP-9100 Navigation Plot Program for Mini-Ranger" by R. Uhrich, NOSC memo 5212-12 of 29 Jun 1977

Instructions for using programs to plot ship's X-Y position. Enter range-range, calculator plots position.

V40 "PTR Static Side Looking Sonar Tests at the San Vicente Dam Test Facility" by PTR Team, NOSC memo 5212-23 of 19 Jul 1977

Report of tests to evaluate various targets, Klein sonar beam underwater, and techniques for recording raw data on magnetic tape. Sonar held stationary and targets moved through beam.

V41 "Klein SLS Detection Capabilities" by R. Uhrich, NOSC memo 6512-187 of 11 Jan 1977

Preliminary estimates of detectable range for two marginal targets (9" and 18" spheres). Calculations based on sonar equations and Klein specifications.

V42 "Preliminary SLS Lateral Range Function" by PTR Team, NOSC memo 5212-41 of 24 Aug 1977

Comprehensive report of means by which data was taken, reduced, and analyzed to give constrained lateral range functions for 7" and 14" spheres using Klein SLS.

V43 "360° Beam of Klein Sonar" by R. Uhrich, NOSC memo 5212-54 of 22 Sep 1977

Presents sonogram evidence that Klein SLS records objects directly below and directly above.

V44 "Best Unimodel Approximation in the Weighted Least Squares Sense on a Discrete Set" by L. Arnold, of Wagner Associates, dtd 22 Aug 1977

Mathematical description of method of finding "best" unimodal function to approximate data which is not necessarily unimodal.

V45 "A version of the 'Pool-Adjacent-Violators' Algorithm and Applications" by L. Arnold of Wagner Associates, dtd 29 Aug 1977

General description of algorithm, application in determining LRF, and mathematical details.

V46 "AUSS PTR Team Data Collection Techniques" by L. Arnold of Wagner Associates, dtd 30 Aug 1977

Agreement with PTR targets and data techniques in general, but suggests each target be treated discretely, rather than in "bins". (This would require more accurate range data on "missed" targets than PTR capability.)

V47 "Constrained Lateral Range Curve Estimation Programs" by L. Arnold of Wagner Associates, dtd 7 Sep 1977

Description and listing of BASIC program for producing LRF.

V48 "Oceanic Data Base Information Exchange Workshop Proceeding (February 1977, San Diego, California)" of 26 Sep 1977

Complete proceedings of workshop of V30.

V49 "Division use of Motorola Mini-Ranger" by S. Watson, NOSC memo 5211-112 of 7 Oct 1977

History and potential future uses of Mini-Ranger. Reasons why Division should purchase.

V50 "Pitch Instability of Side Looking Sonar" by R. Uhrich, NOSC memo 5212-63 of 18 Oct 1977

Sonogram evidence that low translation speeds result in pitch instability. Discussion of potential solution.

V51 "FY77 PTR Status Report" by J. M. Walton, NOSC memo 5212-66 of 27 Oct 1977

Purpose, brief history, and plans of PTR.

V52 "Bathymetric Chart for PTR Deep operations" by J. M. Walton, NOSC memo 5212-10 of 7 Nov 1977

Bathymetric chart of deep operations area and methods by which survey was performed using Mini Ranger, Fathometer, and PTR navigation techniques.

V53 "Telecon with Norm Estabrook" by S. Watson, NOSC memo 6511-256 of 8 Nov 1976

Provides information of SUBDEVGRUONE purchase of Klein SLS and radar transponder navigation system. Opens possibility of cooperation in use of sonar, and even borrowing it for Hawaii test.

V54 "Navigation of RUWS Near Ocean Bottom" by S. Watson, NOSC memo 65-1-259 of 10 Nov 1976

Suggests NAVFAC ATNAV should theoretically be capable of tracking RUWS near the bottom, but warns system is old. Suggest Gene Edgerton as expert.

V55 "SLS Test Target Alternatives" by R. Uhrich, NOSC memo 6512-122 of 18 Nov 1976

Discusses target needs relevant to V-41. Concludes fluid-filled spheres are only quantifiable omnidirectional passive targets. Suggests focussed fluid-filled spheres for high target strength.

V56 "Slip Ring Interference during Encinitas Sonar Tests" by S. Watson, NOSC memo 5211-123 of 7 Nov 1977

Evidence of and possible impact of poor slip rings.

V57 "PTR Annotated Bibliography" by R. Uhrich, NOSC memo 5212-71 of 11 Nov 1977

Annotation of all PTR memoranda and publications. Updated as necessary to remain current.

V58 "PTR FY77 Status Summary and FY78 Plan (Presentation to John Freund)" by J. Walton, NOSC memo 5212-74 of 17 Nov 1977

Presentation of 15 November, includes FY77 chronology, objectives, achievements, and proposed FY78 work.

V59 "Requirements and cost breakdown for Side-Looking Sonar Site Surveys" by J. Walton, NOSC memo 5212-72 of 15 Nov 1977

Time and cost breakdown for load and distant hypothetical operation to survey one square mile with SLS; including bathymetry and data reduction.

V60 "Method of Optimizing Correlation between two Navigation Systems" by R. Uhrich, NOSC memo 5212-75 of 17 November 1977

Derivation of equations and presentation of deep data used to optimize the fit of two sets of data points, one based on ATNAV and one on Mini Ranger.

V61 "PTR Deep Ops Test Plan" by J. Walton, NOSC memo 5212-76 of 17 Nov 1977

Detailed, day-by-day breakdown of test plans and procedures for 1000-foot operations.

V62 "Code 521 Participation in Wake Island Search for C-130 Wreckage" by S. Watson, NOSC memo 5211-128 of 22 Nov 1977

Chronology of events and critique of logistics during subject operation.

V63 "California Shipwrecks" by Diving Officer, NOSC memo 314-91 of 26 Aug 1977

Charted locations of California shipwrecks, and discussion of potentially interesting sites for SLS evaluation.

V64 "Drift of ATNAV Transponders and SLS Targets during Deep Operations" by R. Uhrich, NOSC memo 5212-77 of 5 Dec 1977

Use of Mini Ranger, ATNAV, SLS, and equations of V60 to determine drift of objects during 1000-foot descent, indicates drift negligible amount (15 ft. average) for targets.

V65 "Position Plot Program for AMF 301 and Mini Ranger" by R. Uhrich, NOSC memo 5212-78 of 9 Dec 1977

Derivation of and instruction for use of program, using HP 9100, to plot ship and fish position; based on Mini Ranger and AMF 301 data, and provided at request of SUBDEVGRU-1.

V66 "Changing Mini Ranger Transponder Sites" by R. Uhrich, NOSC memo 5212-80 of 12 Dec 1977

Instruction for using HP-97 program for changing from one transponder site to another without disrupting Mini Ranger position plot.

V67 "Empirical Cable Dynamics Data from 1000-foot SLS Tow" by J. Walton, NOSC memo 5212-84 of 29 Dec 1977

Empirical steady state cable dynamic data derived from deep ops measurements and provided for comparisons with AUSS model predictions.

V68 "PTR Deep Operations SLS Target Data" by J. Walton of 30 Dec 1977, NOSC memo 5212-86

Tabulation of deep op target array contacts vs opportunities based on ATNAV. Overall probability of detection of an array approximately 41%.

V69 "Test Report; Advanced Unmanned Search System Portable Test Range (AUSS PTR) Deep Operations" by PTR Team, NOSC memo 5212-14 of 24 Jan 1978

Detailed report on all aspects of 1000-foot operations using SLS from TRB, ATNAV with "fish cycle," and Mini Ranger.